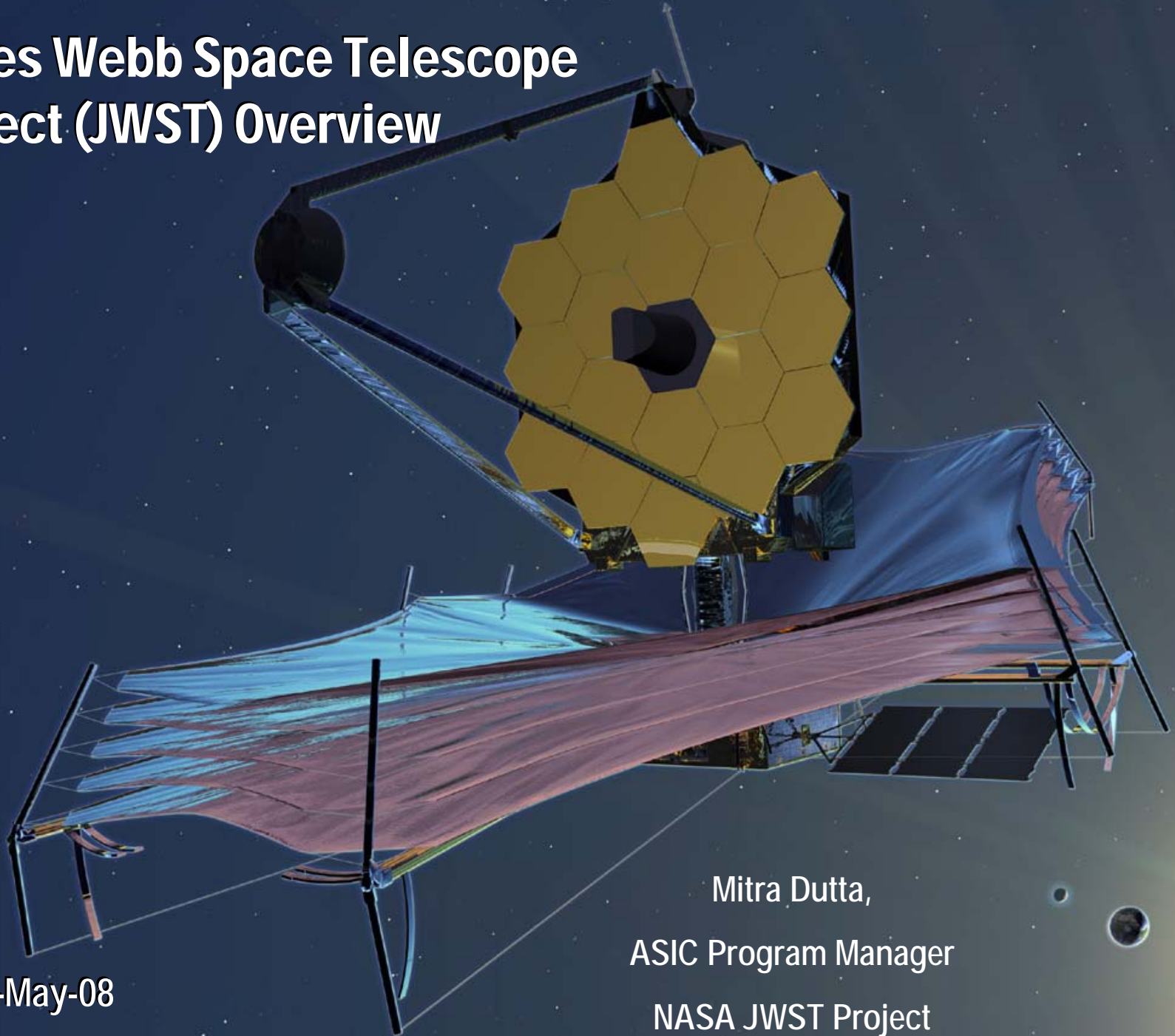


James Webb Space Telescope Project (JWST) Overview

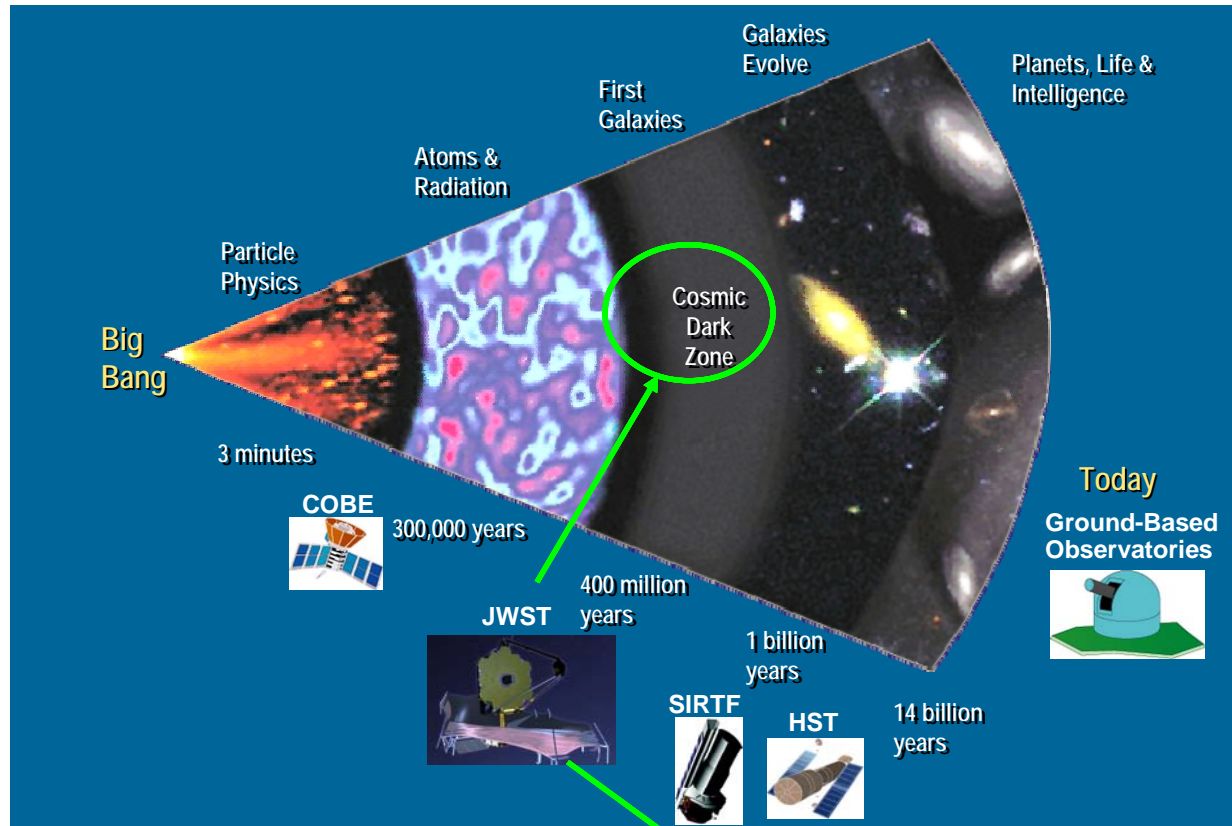


21-May-08

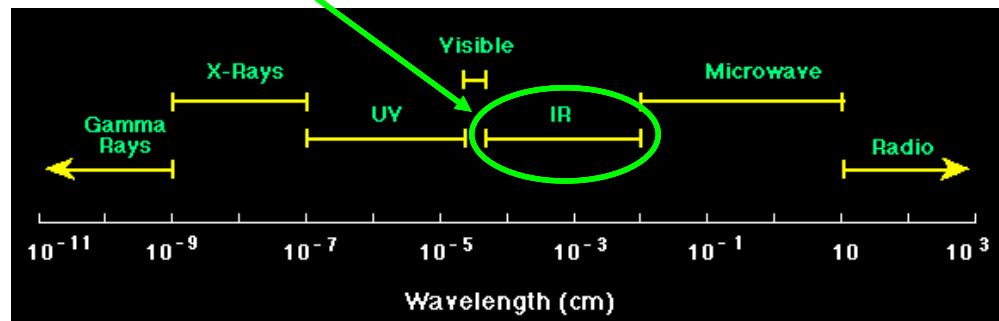
Mitra Dutta,
ASIC Program Manager
NASA JWST Project



Why build an Infrared Telescope?



JWST
designed to
collect data in
this region.

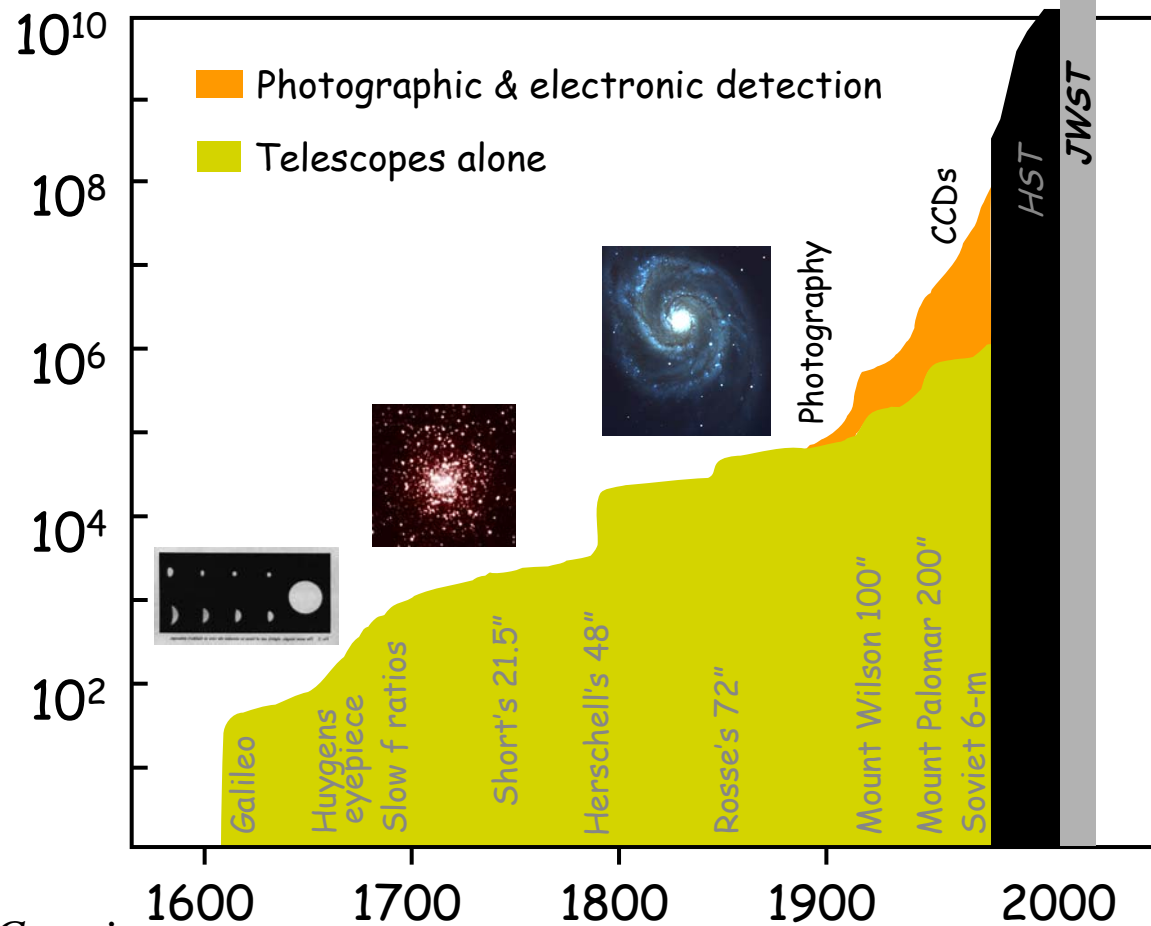




How to win at Astronomy (Size counts)

Big Telescopes with Sensitive Detectors In Space

Sensitivity
Improvement
over the Eye



Adapted from *Cosmic
Discovery*, M. Harwit



James Webb Space Telescope (JWST)

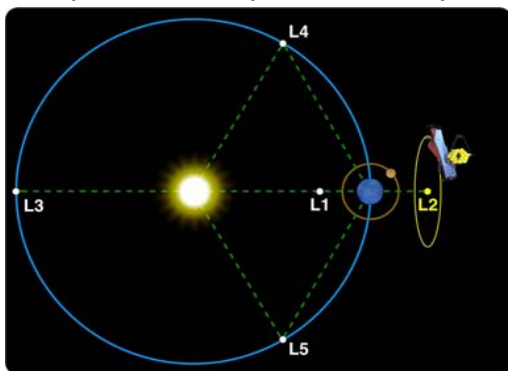
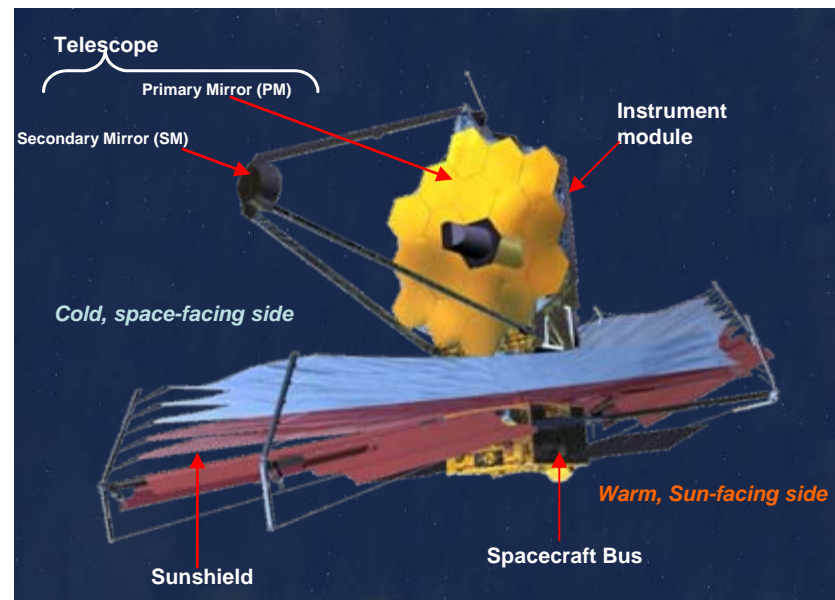
Mission Objective

- Study the origin and evolution of galaxies, stars and planetary systems

Optimized for infrared observations (0.6 – 28 μm)

Organization

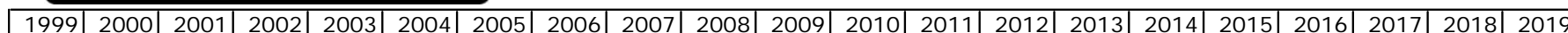
- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Space Technology
- Instruments:
 - Near Infrared Camera (NIRCam) – Univ. of Arizona
 - Near Infrared Spectrograph (NIRSpec) – ESA
 - Mid-Infrared Instrument (MIRI) – JPL/ESA
 - Fine Guidance Sensor (FGS) – CSA
- Operations: Space Telescope Science Institute (STScI)



Description

- Deployable telescope w/ 6.5m diameter segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch NET June 2013 on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)

www.JWST.nasa.gov



Concept Development

Design, Fabrication, Assembly and Test

science operations



Phase A



Phase B



Phase C/D



Phase E

Formulation
Authorization

ICR
(PNAR)

NAR

Launch



JWST Full Scale Model at the GSFC





JWST vs HST - Specifications

HST

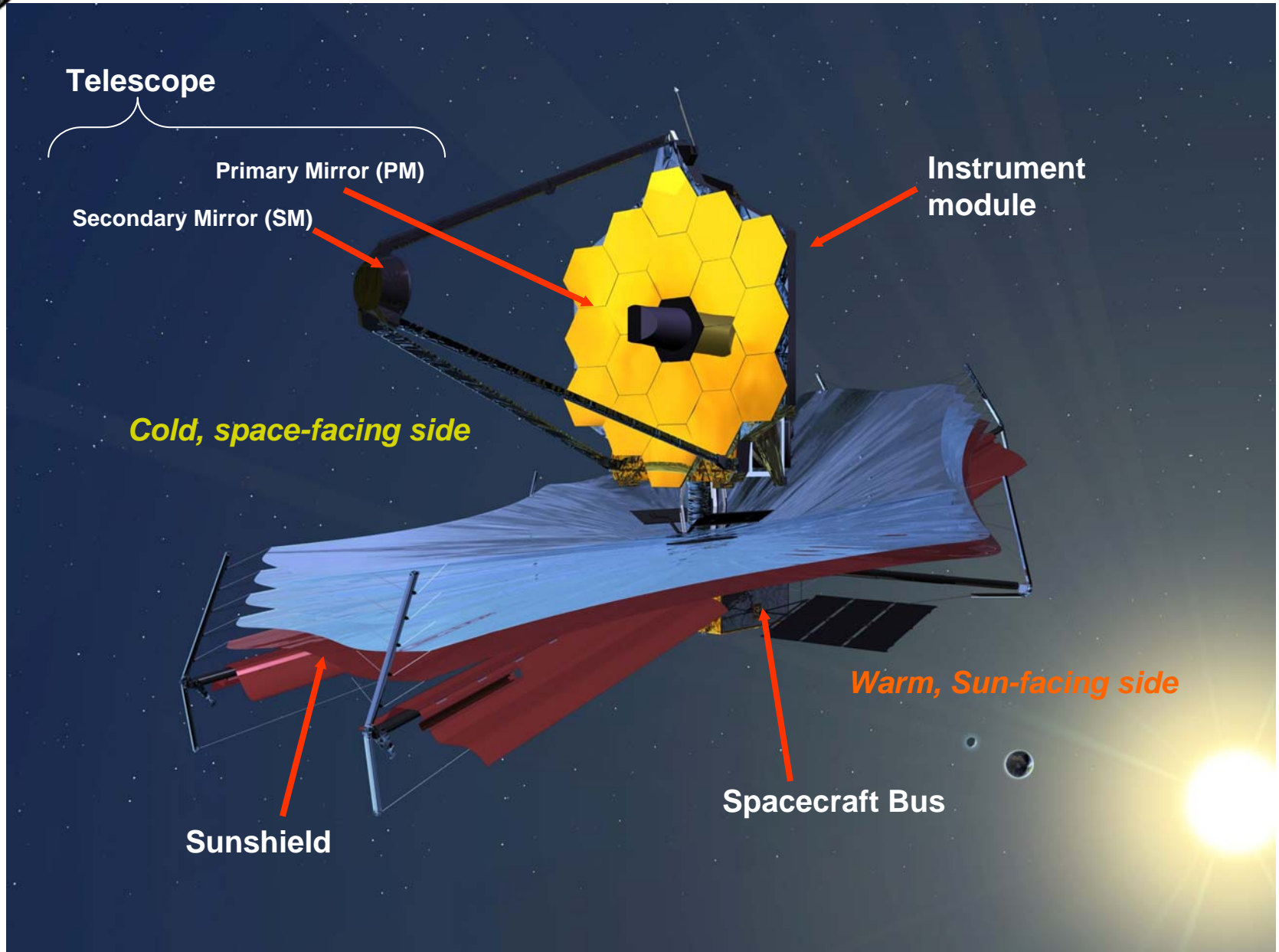
- 2.4 meter Primary Mirror
- LEO orbit (95 minutes)
- 0.1 to 2.5 microns coverage
 - Faint Object Camera (FOC)
 - Wide Field/Planetary Camera (WF/PC)
 - Space Telescope Imaging Spectrograph (STIS)
 - NICMOS
 - Advanced Camera for Surveys (ACS)
 - Fine Guidance Sensor (FGS)
- NICMOS cryocooled to ~ 77K
- 100 milliarcsecond resolution
- Launched in 1990

JWST

- 6.5 meter deployable Primary Mirror
- L2 orbit (1.1 year)
- 0.6 to 27 microns coverage
 - Near Infrared Camera (NIRCam)
 - Near Infrared Spectrometer (NIRSpec)
 - Mid-Infra-Red Instrument (MIRI)
 - Fine Guidance Sensor (FGS)
- 5 year life requirement
- Passively cooled to ~ 37K
- MIRI cryocooled to ~ 7K
- 64 milliarcsecond resolution
- Tennis court size sunshield
- Launch in 2013



JWST Observatory



AXSYS

TECHNOLOGIES





The JWST mission architecture is optimized to enable key science requirements

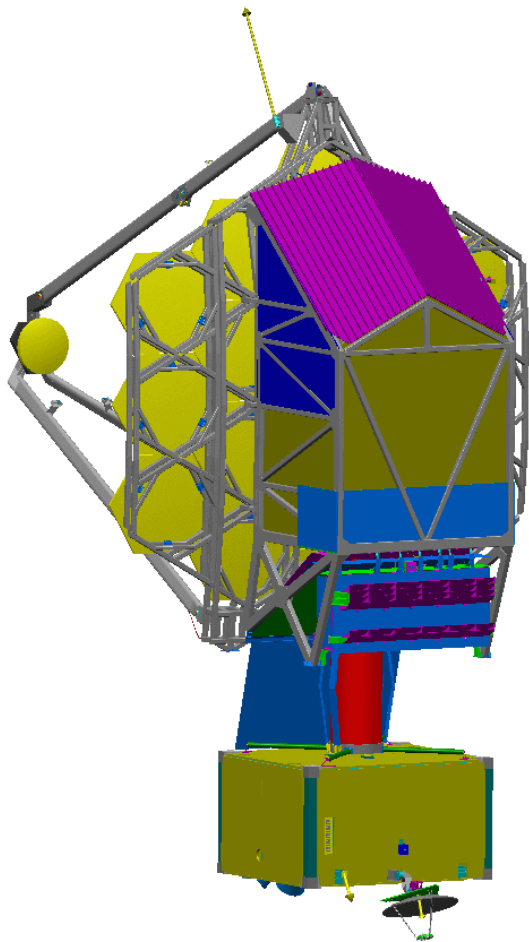
- **JWST sees in the infrared because that is where its science is**
 - Light waves have been stretched by the expansion of space since the Big Bang. Visible light emitted by the first stars and galaxies has been shifted into the infrared by the time it reaches us.
 - Light from star and planet forming regions and from planets themselves is brightest in the infrared.
- **Large telescope optics collect and focus light**
 - With telescopes, size matters
 1. **Resolution** – objects of interest are far away and appear small. The bigger the aperture, the more detail you can see. We need to see details of structure to identify what we are observing.
 2. **Sensitivity** – objects of interest are far away and are faint. The bigger the aperture, the more light we gather and the fainter are the objects we can detect.
- **JWST's telescope is lightweight and deployable so it can be launched economically**
 - The required size of the main mirror is wider than any available or practical launch vehicle. Making its telescope lightweight and deployable makes JWST's large size feasible and affordable.
- **Telescope and Scientific Instruments are cold for sensitivity**
 - Infrared light is heat radiation. The telescope and the instruments (cameras and spectrometers) attached to it need to be cold so that their own warmth does not overwhelm the faint infrared signals they are trying to detect.
 - The detector chips at the heart of each instrument must be cold in order to function.
- **Sunshield allows the telescope and instruments to get cold**
 - The sunshield shades the telescope and instruments from the Sun, allowing them to radiate their heat to the extreme coldness of deep space and become very cold themselves
- **L2 is an ideal place for an infrared observatory**
 - The Sun-Earth L2 point is far enough away from the warm Earth to provide a benign thermal environment and enable efficient operations, yet close enough for easy launch and communications



The science payload is integrated to avoid duplication of common science instrument systems

ISIM is:

- **The JWST Science Instruments**
- **Associated Infrastructure: Structure, C&DH, & FSW**



Region 1

Science Instrument Optics Assemblies

Near Infrared Camera (NIRCam)

Near Infrared Spectrograph (NIRSpec)

Mid Infrared Instrument (MIRI)

Fine Guidance Sensor and Tunable Filter (FGS/TF)

Optical Bench Structure

Radiators and support structure (NGST-supplied)

Region 2

Focal Plane Electronics (FPE)

Instrument Control Electronics (ICE, MCE)

ISIM Remote Services Unit (IRSU)

Region 3

ISIM Command & Data Handling (ICDH) Electronics

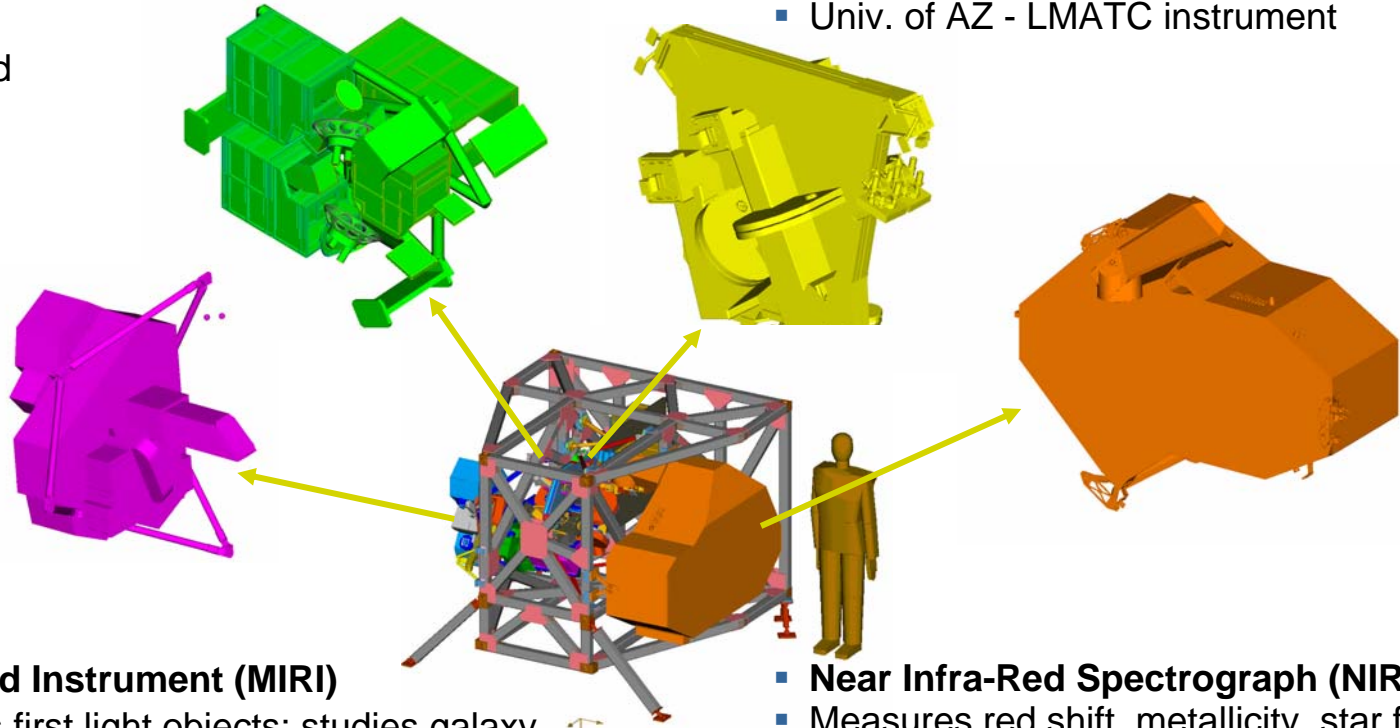
MIRI Cryocooler Electronics



Instrument Overview

- **Fine Guidance Sensor (FGS)**
- Ensures guide star availability with >95% probability at any point in the sky
- Includes Narrowband Imaging Tunable Filter Module
- CSA provided

- **Near Infra-Red Camera (NIRCam)**
- Detects first light galaxies and observes galaxy assembly sequence
- 0.6 to 5 microns
- Supports Wavefront Sensing & Control
- Univ. of AZ - LMATC instrument



- **Mid-Infra-Red Instrument (MIRI)**
- Distinguishes first light objects; studies galaxy evolution; explores protostars & their environs
- Imaging and spectroscopy capability
- 5 to 27 microns
- Cooled to 7K by Cyro-cooler
- Combined ESA/JPL contributions

- **Near Infra-Red Spectrograph (NIRSpec)**
- Measures red shift, metallicity, star formation rate in first light galaxies
- 0.6 to 5 microns
- Simultaneous spectra of >100 objects
- Resolving powers of ~100 and ~1000
- ESA provided with NASA Detectors & Micro shutter



JWST Roles and Responsibilities



- **GSFC**
 - Management & Systems Engineering
 - NIRSpec Micro-Shutter and Detector Subsystems
 - ISIM C&DH Electronics/Software
 - ISIM Structure and Thermal Subsystem
 - ISIM-level I&T



- **European Space Agency/European Consortium**
 - NIRSpec Instrument
 - MIRI OBA (Optical Bench Assembly) and I&T



- **Canadian Space Agency**
 - FGS including FGS/TF



- **University of Arizona**
 - NIRCам Instrument (Lockheed Martin ATC is Prime)



- **JPL**
 - MIRI Management & Systems Engineering
 - MIRI Detector Subsystem, Dewar, and Flight Software

JWST Prime Contractor Team (NGST, Ball, Kodak, ATK)

- ISIM Enclosure & Interface-related GSE



- **Space Telescope Science Institute**
 - Instrument Support for Flight and Science Operations



- **Teledyne Imaging Sensors**
 - NIR Detectors & ASIC

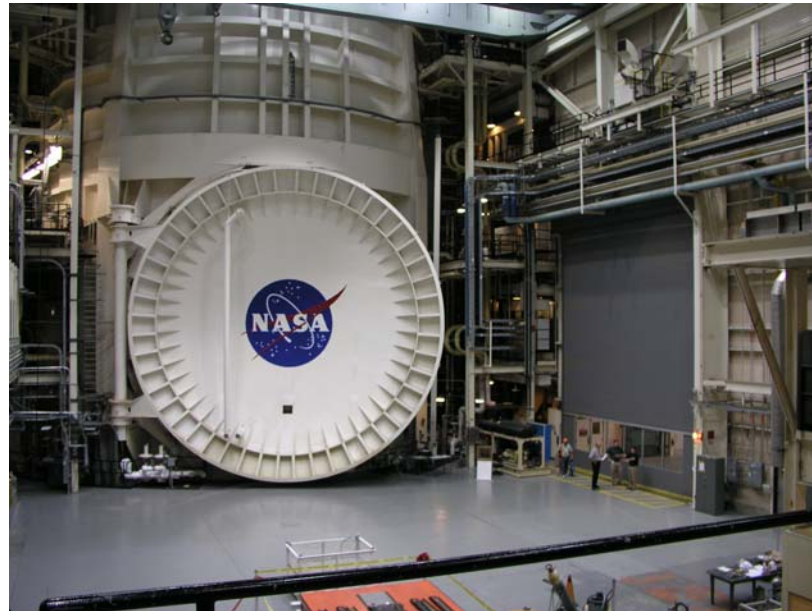


- **Raytheon Corporation**
 - MIR Detector



An on-line space simulation chamber enables JWST cryogenic testing

		<u>JSC Chamber A</u>
Chamber size		55' diam, 117' high
Existing Shrouds		LN2 shroud, GHe panels
Chamber Cranes		4x25t fixed, removable
Chamber Door		40' diam
High bay space		~102'Lx71'W





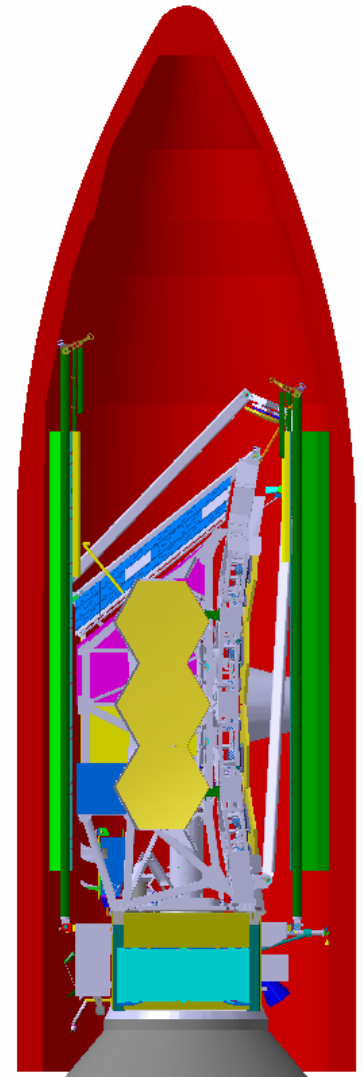
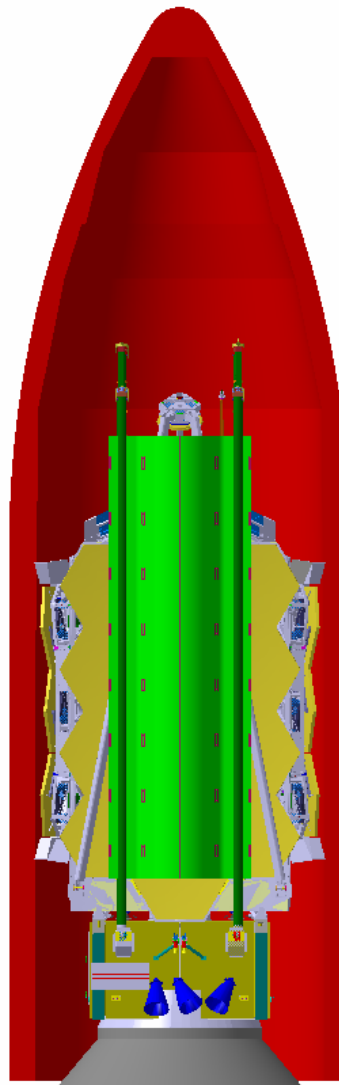
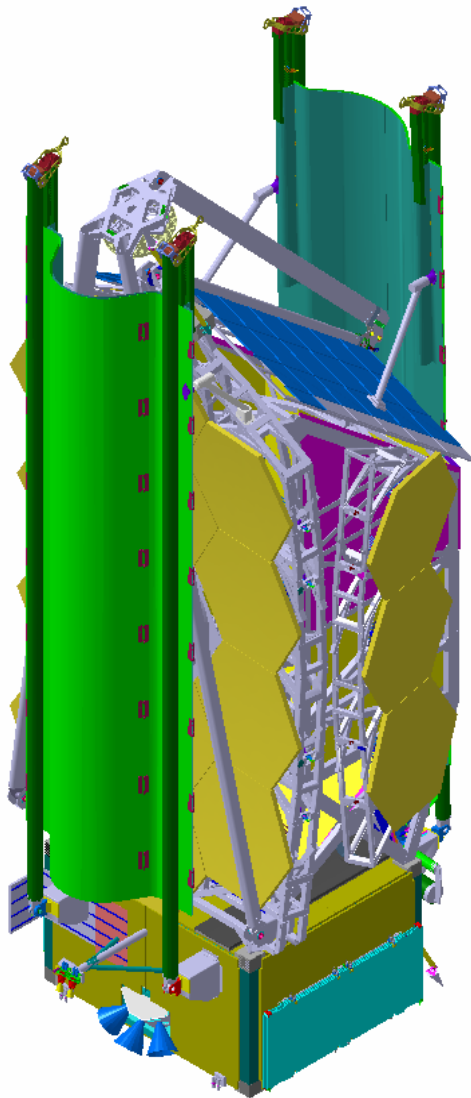
The JWST will utilize an existing transportation system

U.S. Air Force Space Cargo Transportation System (SCTS)



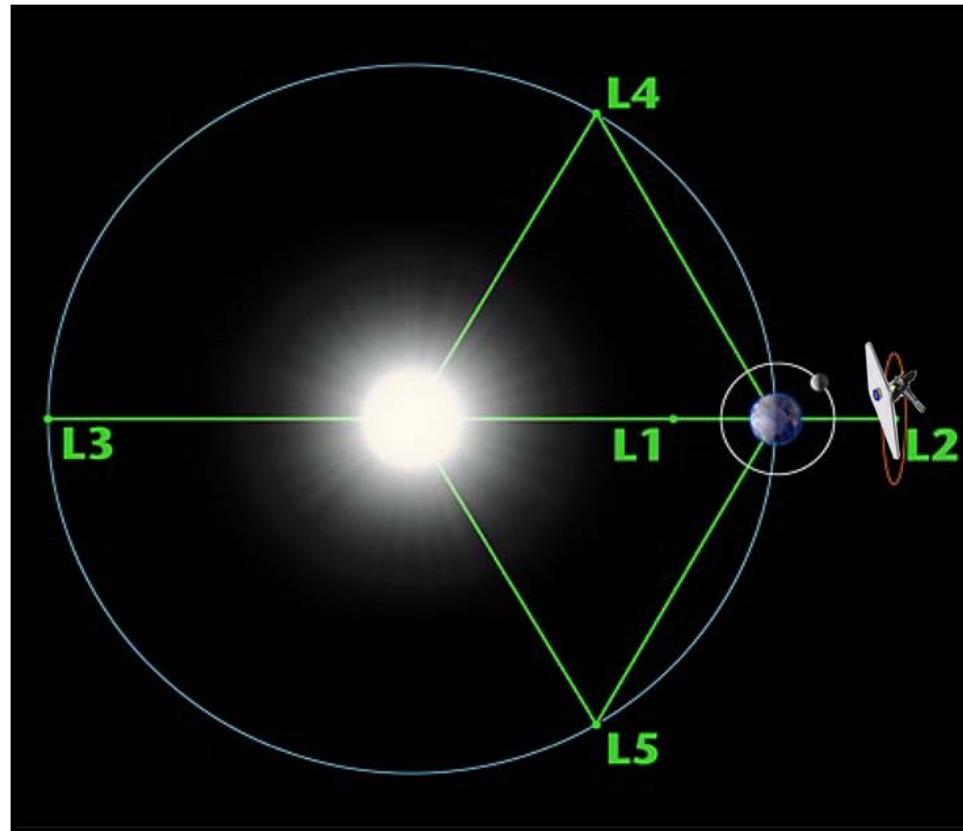


The JWST is designed to utilize standard Ariane 5 launch service contributed by ESA





JWST Operational Orbit Around Sun-Earth L2 Point

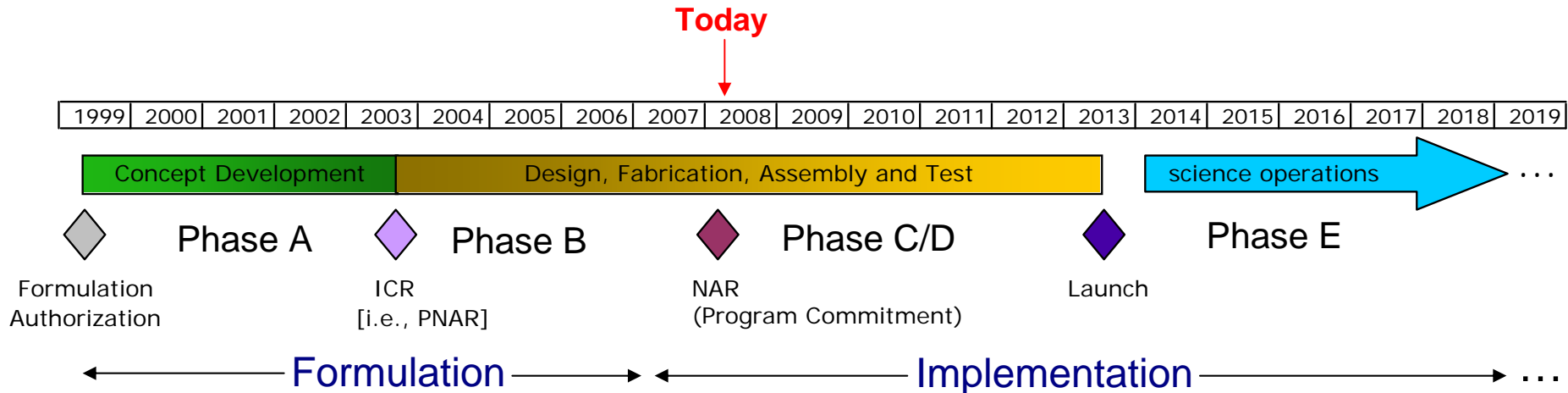


- Sun-Earth L2 is a location in space where gravities of the Sun and Earth combine to form a local equilibrium point which follows the Earth around the Sun
- JWST will orbit about the L2 point, roughly 1.5 million kilometers from the Earth
 - All major heat sources are on one side of the observatory, (Sun, Earth, Moon)
 - This allows the sunshield to constantly shade the telescope and instruments to enable passive cooling to cryogenic temperatures





JWST Program Today



- **Early emphasis on vigorous technology development to retire risk**
 - All new technology development are already at TRL-6 and flight production started.
- **JWST technology investments enable future science missions**
 - TPF, SAFIR, SPIRIT, SPECS and CON X use technology developed by JWST



JWST technology readiness is measured against formal non-subjective criteria

- TRLs are used to systematically assess the maturity of technologies
 - NASA uses a nine step TRL scale (from NPR 7120.5C):

System Test, Launch & Operations	TRL 9	Actual system “flight proven” through successful mission operations
	TRL 8	Actual system completed and “flight qualified” through test and demonstration (ground or space)
System/Subsystem Development	TRL 7	System prototype demonstration in a space environment
	TRL 6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)
Technology Demonstration	TRL 5	Component and/or breadboard validation in relevant environment
	TRL 4	Component and/or breadboard validation in laboratory environment
Technology Development	TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept
	TRL 2	Technology concept and/or application formulated
Research to Prove Feasibility	TRL 1	Basic principles observed and reported
Basic Technology Research		

- NASA Management Handbook requires that mission-enabling technologies reach TRL 6 before the Project is confirmed



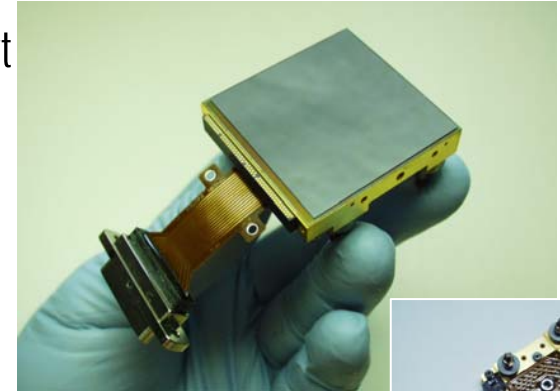
Early ISIM technology investments have paid off

■ Infrared Detector Technologies:

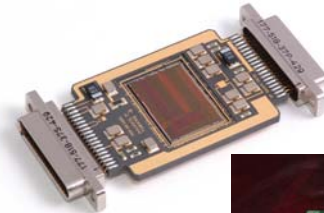
- HgCdTe Detectors used for NIRCам, NIRSpec, and FGS
 - JWST funding significantly advanced the state-of-the-art as represented by the HST/NICMOS 256x256 arrays
 - Grew detector format by 64X to 2048x2048 pixels
 - Doubled wavelength coverage, pushing long-wave cut-off from 2.5 microns to 5.0 microns
 - Lowered dark current by 10X
- SiAs Detectors used for MIRI
 - Pushed technology beyond the SIRTf/IRAC 256x256 arrays
 - Grew format 16X to 1024x1024 pixels

■ Cryogenic ASIC Technology for noise immunity:

- NIRCам, NIRSpec and FGS instruments use ASICs to digitize analog detector signal and send over 4 meter cable length maintaining ultra-low noise
 - "Cryo ASIC" essentially developed for JWST
 - Technology brought from TRL1 to 6 in five years with JWST funding and RSC support



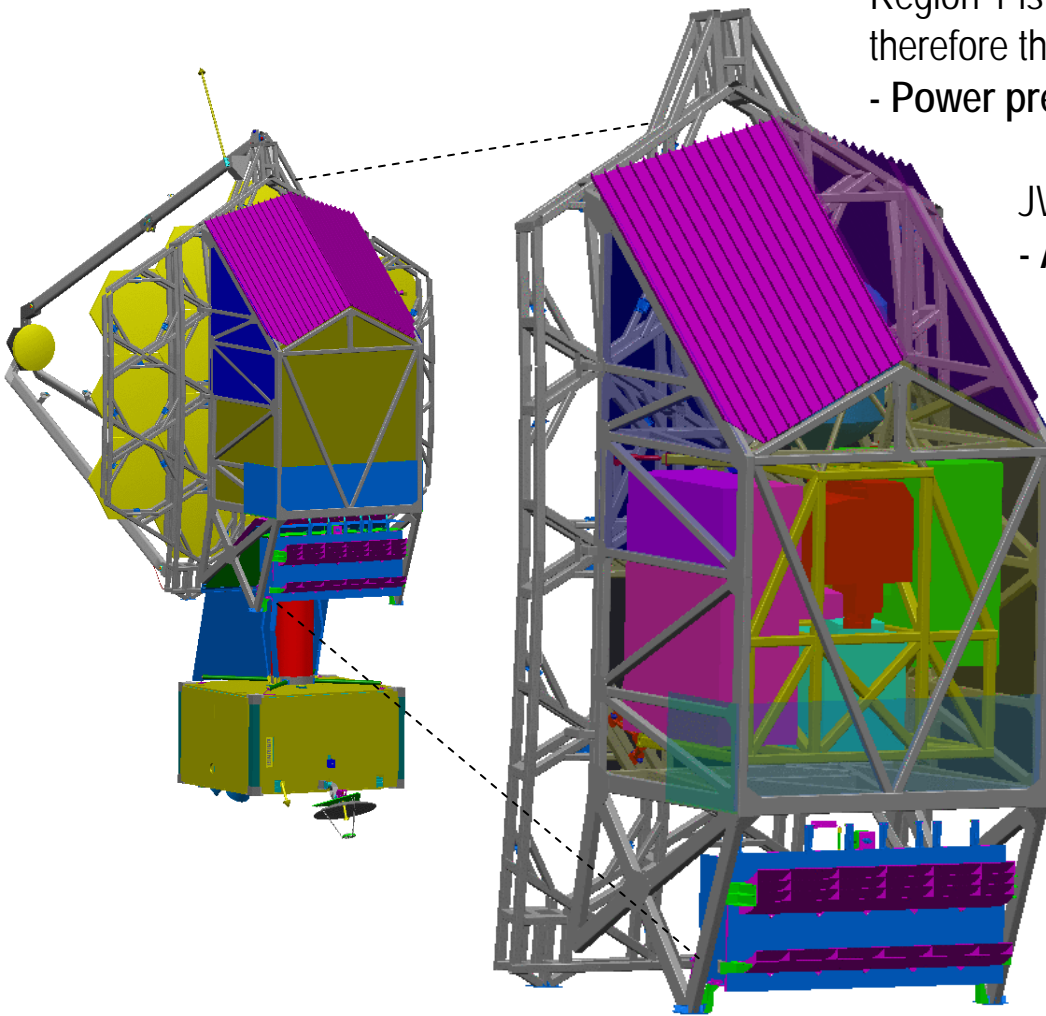
2Kx 2K HgCdTe
Sensor Chip Assembly



2Kx 2K Cryo ASIC in Package
& JADE card Assembly



Key Issues for ASIC Decision



Region 1 is cold ($\sim 40\text{K}$) & has limited radiator area, therefore the ASIC power dissipation is important.

- Power predictions should be accurate to $<1\text{mW}$

JWST needs to survive ~ 5.5 years in L2 Orbit

- ASICs must be spaceflight qualified.

To meet JWST sensitivities, NIRCам, NIRSpec, and FGS must be very low noise, on order of 6-10 e- total.

- ASIC must meet or beat noise performance of baseline analog electronic design.

ASICs must meet JWST schedule.

- ETUs delivered \sim Nov 05/Aug 06
- Flight ASICs \sim May 06/ Mar 07

Without the ASIC, there is a ~ 4 meter cable run between Detectors and Electronics (A/D, clocks, etc), therefore EMI crosstalk is a concern.

- We'd like to define (quantify) the improvement in EMI immunity in ASIC vs non-ASIC solution.